A BATTERY FOR MY FUEL CELL?

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INTRODUCTION

Over the past several years, the interest in long run-time applications has grown dramatically. Incidents from the New York blackout to Katrina have uncovered needs that may have previously gone unnoticed. Hydrogen fuel cell designs are emerging as a potential cure all in these long run-time applications.

This paper will provide a background on fuel cells; describing some typical applications and the need for additional bridge power. It will then focus on design attributes of lead acid batteries and how Thin Plate Pure Lead batteries ideally match the application needs of fuel cells.

FUEL CELL BACKGROUND

Fuel cells have been in existence for many years, getting their start in aerospace applications that were insensitive to the expensive materials and labor intensive processes necessary to produce them. The high price of this technology limited it to these special applications and fuel cell use in more terrestrial applications was limited. In recent years, however, new developments in materials and manufacturing processes have allowed the cost of fuel cells to drop significantly, opening up the possibility of using fuel cell technology for applications that previously would not support their high price. With proper design, reserve power applications can take advantage of the most desirable aspects of fuel cells while still maintaining the instant availability that batteries or other energy storage devices allow. Fuel cells and batteries integrated into a hybrid power system can produce a superior solution in many applications.

Fuel cells convert a fuel, most commonly hydrogen, directly into electrical energy. In the case of the PEM fuel cell this is achieved by bringing hydrogen fuel in direct contact with a catalyst coated polymer membrane. The proton from the hydrogen fuel that is in contact with the catalyst moves through this membrane while the electron travels through an electrically conductive path to the desired load.

Applications currently being explored for fuel cells include telecom backup, UPS applications as well as motive power applications that allow for users to capitalize on the unique performance characteristics a fuel cell provides. Due to the ability of a fuel cell to produce electrical power by direct conversion of a replaceable fuel, they offer power back up that is only limited by the amount of fuel that can be stored. Reserve Power systems currently being designed can easily offer over 60 kW-hr of backup power in a single bay rack enclosure. This energy can be quickly restored by replacing the spent fuel cylinders with new fuel cylinders making available another full 60 kW-hr of energy within a matter of minutes. Another advantage of this type of system is the ability to refuel while under load, thus maintaining continuous power for extended periods of primary power loss.

Fuel cells offer superior performance in the area of end user emissions, producing clean power whose only emissions are water and heat. This can be of particular advantage when these systems are used in areas where diesel generator emissions or noise are an issue. A fuel cell can operate in near silence in either an indoor or outdoor environment.

TYPICAL FUEL CELL APPLICATION

UPS and backup power applications can benefit greatly from the addition of fuel cell power generation by extending the area of performance beyond what more traditional battery reserve power solutions can achieve. However, even with the benefits that a fuel cell can offer in this application, a well designed system incorporating an optimized battery solution that can take advantage of the fuel cell's power producing characteristics will offer superior performance over what either technology can achieve on its own.

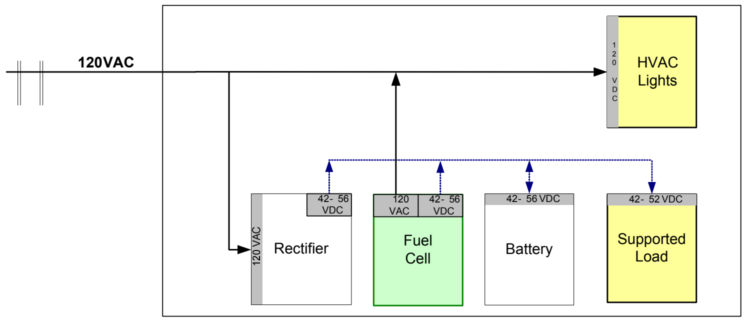

Figure 1 – Typical Fuel Cell System Configuration

A typical backup power situation using a fuel cell to support a DC bus in a telecom backup application is shown in figure 1. This architecture includes both a fuel cell power system and batteries in order to support a critical DC load. The batteries in this system are required to:

- To bridge short power outages and to prevent "short cycling"
- To provide power to the fuel cell during startup
- To provide bridge power to the load during fuel cell warm-up
- To provide load leveling during short power transients and
- To provide power during fuel cell shutdown

Short cycling is a condition where frequent power outages or short power sags cause a fuel cell system to execute a startup but then immediately go into a shutdown cycle before contributing a significant amount of energy to the load. The battery in this case is used to support the load during this short transient, typically 5 to 10 seconds for most products. During this period the battery is expected to supply the full power needed by the load, usually in the range of 2 to 10kW.

BRIDGE POWER

After a the fuel cell senses that the grid fed rectifiers are no longer supplying power to the system, the fuel cell delays startup for a short period of time in order to minimize the short cycling phenomenon described above. After this delay the fuel cell draws a small amount of power from the batteries to operate the on board control electronics, to start cathode air circulation and to open the valves that admit fuel to the fuel cell stack. After fuel is supplied to the stack the fuel cell begins a warm-up period and starts to produce power.

During the warm-up period a fuel cell ramps its output power from around 50 percent of rated power to full rated power. This typically takes around 20 to 30 seconds. During this time the batteries support the balance of load not immediately supplied by the fuel cell and make this warm-up period transparent to the supported load.

When the fuel cell is at full operation and totally supporting the load, the batteries start to be recharged using any extra capacity from the fuel cell. This period of recharge can be quite rapid and be as high as 50% of the sized load. This rapid recharge requires a battery that is capable of these extremely rapid recharge rates.

After the grid power is restored and the rectifiers again support the load, the battery will provide power to complete shutdown should the grid power be lost before this procedure is completed. Proper fuel cell shutdown is important to extending the stack life, and interruption to this process can significantly shorten the life of the fuel cell.

CALL FOR BATTERIES

For all these reasons a well designed fuel cell system requires an auxiliary form of energy storage, and a cost effective solution is lead acid batteries. However, the batteries that perform best in this configuration are different than those typically utilized in UPS backup situations. The power requirements are high; however the duration and total energy expenditure is a fraction of what would normally be required for a battery only backup solution. This system architecture usually prevents deep battery discharge and loads the battery in a manner that is more conducive to achieving long life. The ideal battery for this architecture has high power discharge and recharge capabilities over a wide temperature range, small size, and long life. The characteristics of TPPL (Thin Plate Pure Lead) batteries complement these requirements well.

HISTORY OF TPPL

Lead acid batteries have been around since the 1800's, and many of the users have an expectation of performance and life. Most technologies are very similar to each other, with the only real differences being in the alloys added to the lead conductors. In general, there are three types of alloys used, flooded pure lead (typically round or Plante cells), Antimony (flooded cyclic applications) and Calcium (flooded or VRLA float applications).

There is, however, one other form of lead acid technology that was developed by the Gates Corporation in the 1970's – the Cyclon pure lead spiral cell. This design utilized very pure, thin lead electrodes and high compression. The end result is a cell that has very low stand loss, low internal resistance, a marked improvement in power density and extremely long life when compared to other lead acid technologies.

In the early 1980's, this spiral technology evolved into prismatic designs for other markets. These products took the proven design principles of the Cyclon product and placed them into prismatic BCI or JIS footprints. Market acceptance of this product offering was overwhelming, and production capacity was added to support both the Telecom and Specialty markets.

The latest evolution of this product design has been targeting even more extreme markets. Markets like the aircraft engine start, the US and British HUMVEE, and the M1A1 Abrams tank. These TPPL designs provide excellent cranking ability in engine start applications (typically 4 or 5 times that of the competition) as well as tremendous advantages in silent watch applications that have typical run times of 4 to 20 hrs.

IDEAL MATCH TO FUEL CELLS

As noted, one of the design considerations for utilizing a fuel cell as a backup is the time it takes to power up. Typically this startup time or "bridge time" is between 5 and 30 seconds. Through the startup time most manufacturers utilize either ultra capacitors or batteries. Both have advantages; however the TPPL products with their low internal resistance, excellent high rate performance, quick recharge capability, 10-year life, no maintenance requirements and attractive costs make them an extremely viable solution versus ultra capacitors and other PbCa technologies.

SELF DISCHARGE

One of the stated drawbacks of lead acid chemistry is the need for periodic maintenance while not in use. This is commonly referred to as top charging or boosting and in general is required every 6 months for lead acid VRLA batteries. The optimized TPPL designs with high purity components and low internal resistance overcomes most of this self discharge phenomenon and enables users to see up to two years of storage time before attention is needed. A chart of the self discharge characteristics is seen in figure (2). This ability to set provides the fuel cell manufactures and users with the ability "to set it and forget it".

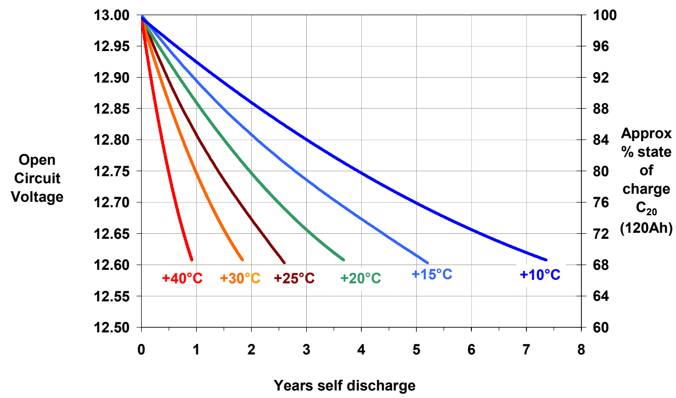

Figure 2 – Self Discharge Characteristics of TPPL

HIGH RATE PERFORMANCE

The low internal resistance and thin electrode design of TPPL batteries result in superior high rate performance as compared to the typical PbCa counterparts. An example of this advantage can be seen in some MIL D8565 testing (figure 3). It is based on data such as this that the TPPL line of products continues its expansion into extreme applications. This benefits fuel cells by allowing smaller, more cost effective batteries to be selected and incorporated into the "core" system design, reducing the expensive real estate required in the final packaged offering.

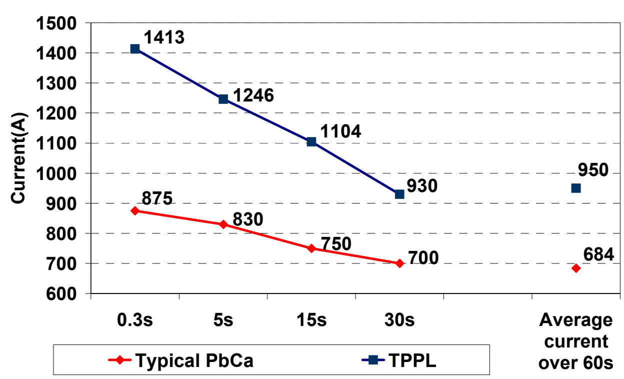

Figure 3 – High Rate Performance of TPPL

CYCLIC PERFORMANCE

Cyclic performance is another area where the TPPL batteries excel over our PbCa competitors. An example of this is demonstrated via a micro-cycle test (figure 4). This test was designed to simulate a fuel cell startup or forklift application – applications where the discharges occur at very high currents for a short period of time and followed by a very rapid recharge. In this specific example, an 70Ah TPPL battery (C_{20}=70Ah) was discharged at a 2kW rate for 10 seconds, rested at OCV for 30 seconds, recharged for 15 seconds at the same 2kW rate and rested again at OCV for 30 seconds. The cycle was then repeated continuously. Every 500th cycle a 3 hr capacity test was done to validate performance. In this testing, the battery exceeded 6000 cycles. This demonstrates the TPPL batteries ability to support both the short cycle and bridge power applications seen in a fuel cell.

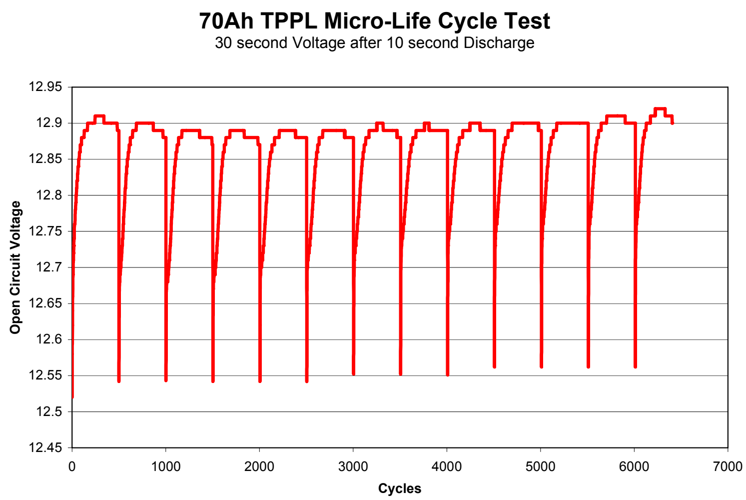

Figure 4 – Micro-cycle Testing of TPPL

RECHARGE CAPABILITIES

Another item of critique for traditional batteries is the time it takes to recharge or to come back to a known state of charge and be ready for an additional discharge. The optimized TPPL design allows the battery to accept very high in-rush charging currents enabling the battery to return to a full state of charge in a period of minutes instead of hours. Most PbCa products limit inrush current to 0.15C or 0.25C; however the TPPL batteries can accept up to 8C! A typical chart of the recharge times for TPPL is shown in figure 5. It is notable to see that using a 2.40VPC constant voltage recharge, the battery with 25% SOC returns to 80% state of charge in fewer than 11 minutes

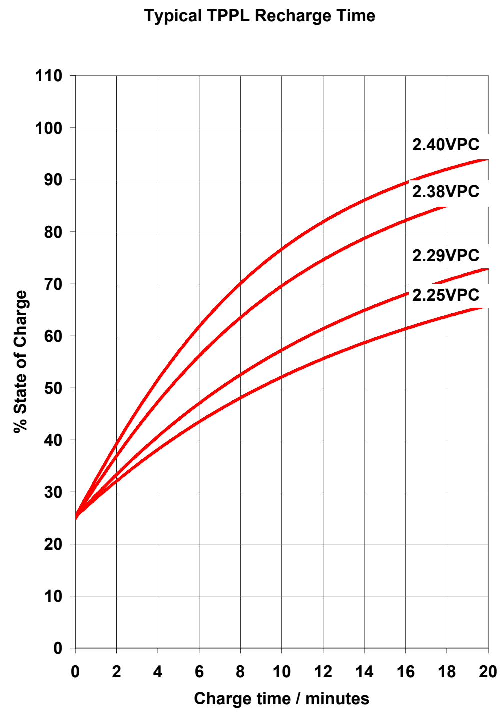

Figure 5 – Recharge Characteristics of TPPL

SUMMARY

Today's fuel cell designs are maturing at a rapid pace and may evolve into robust cost effective replacements for long-runtime applications. A PEM fuel cell designed with a "Keep It Simple" approach, an eye towards costs, an understanding of previous design iteration failures and designed for ease of high speed manufacturing could be the solution that revolutionizes the marketplace.

Regardless of the manufacturer or fuel cell design, what has become apparent is the need for interim backup power for short cycle and bridge power applications.

The unique design attributes of low internal resistance, excellent high rate and cyclic capability, quick recharge, 2-year shelf life, demonstrated 10 yr no maintenance life while being cost effective make Thin Plate Pure Lead batteries the preferred solution for this emerging market.

ACKNOWLEDGEMENTS

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